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(54) **Tactile sensor**

(57) In a tactile sensor of the kind comprising a compressible mat (1) of electrically resistive material and an array of electrodes (3, 5) on at least one main face of the mat the electrically resistive material comprises filaments coated with electrically conductive material. Information regarding the shape, position, pressure exerted by an object can be obtained by scanning the resistance between pairs of electrodes. The filaments may be fibres of a natural or synthetic material. The sensed output may be fed to a microprocessor.

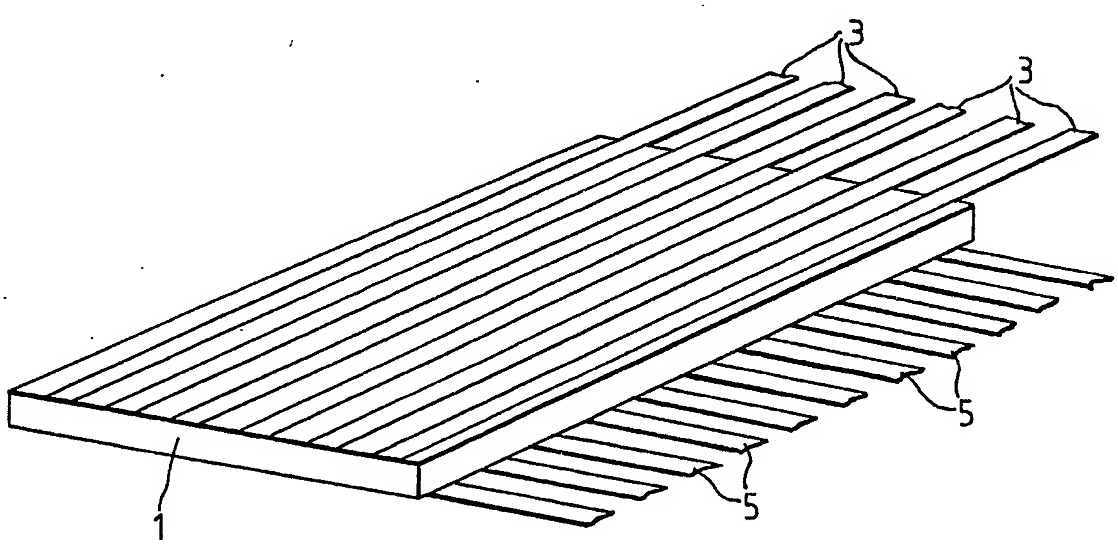

Fig.1.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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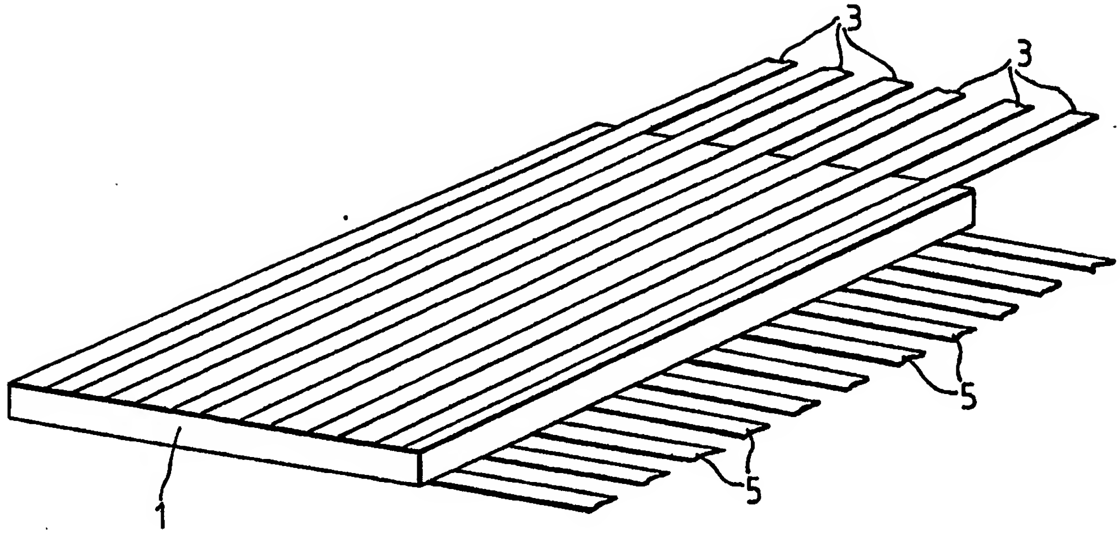

Fig.1.

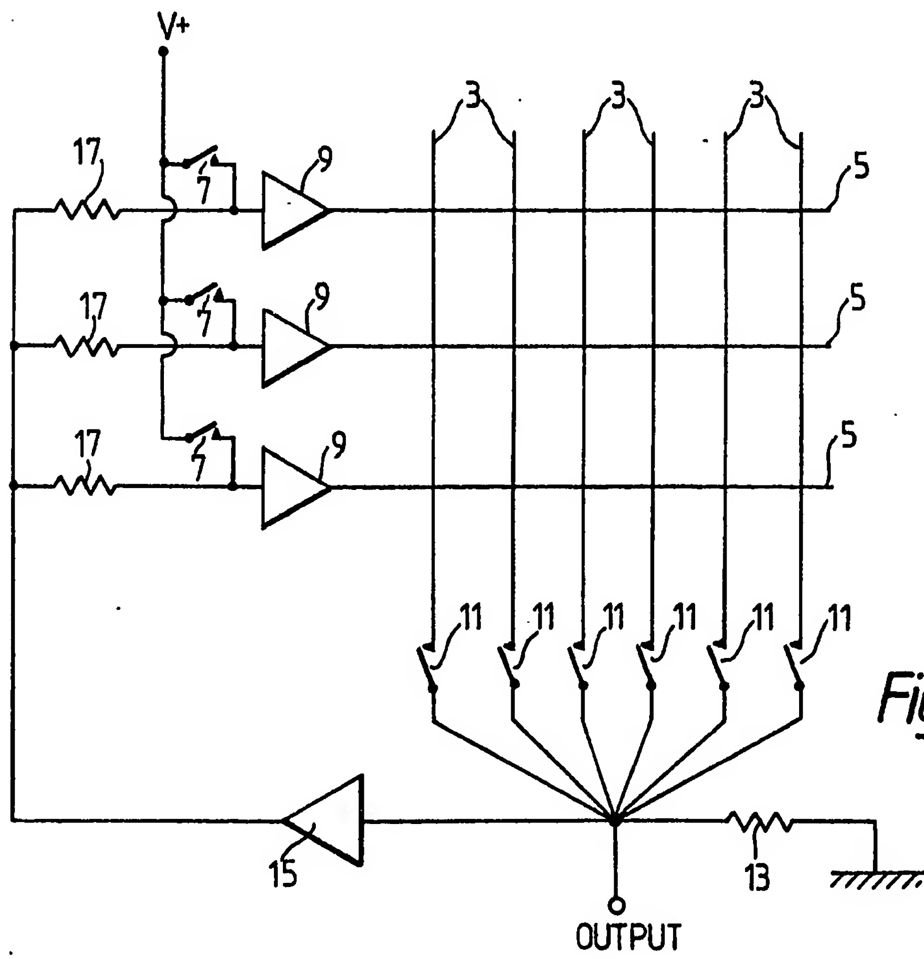

Fig.2.

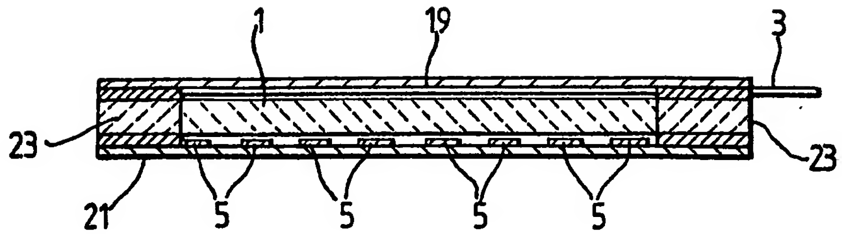
1
19
3
23
23
21
5
5
5
5

Fig. 3.

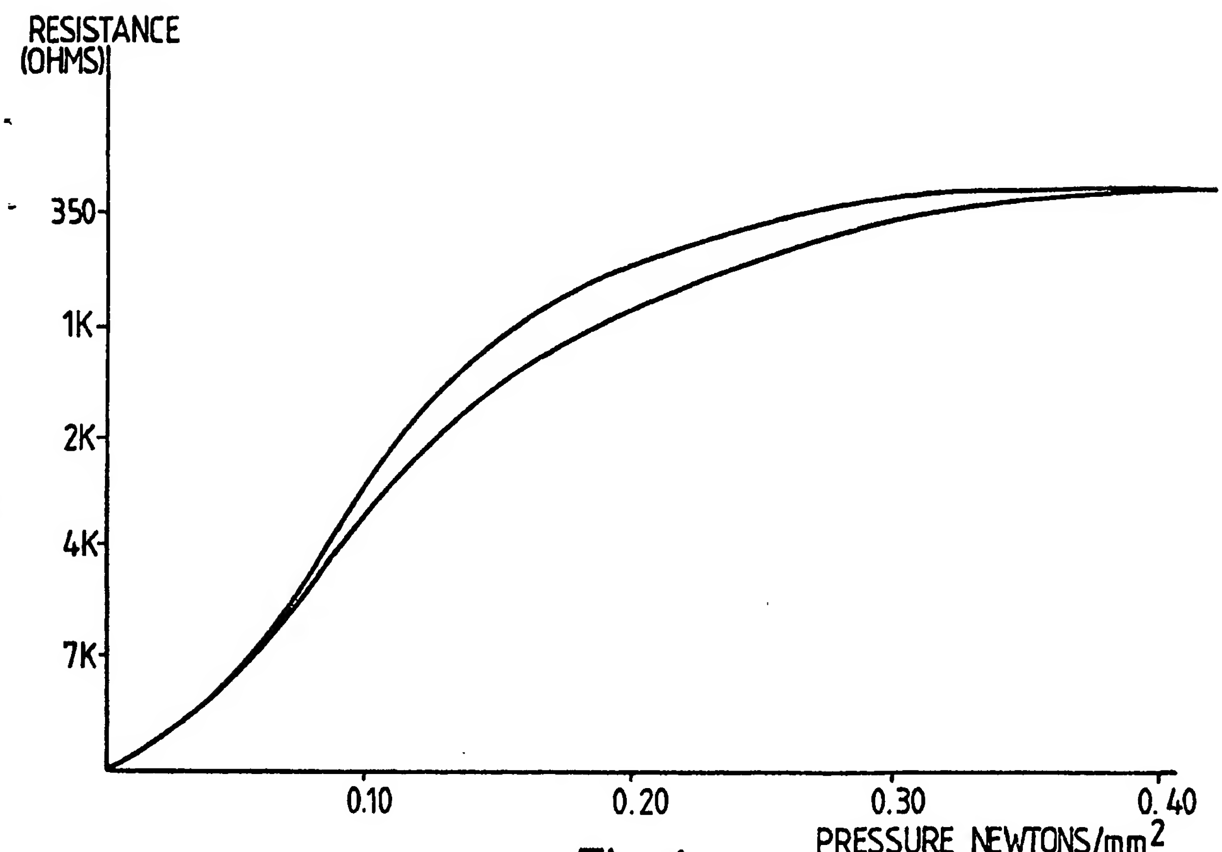
RESISTANCE (OHMS)
350
1K
2K
4K
7K
0.10
0.20
0.30
0.40
PRESSURE NEWTONS/mm2

Fig. 4.

SPECIFICATION
Tactile sensors

This invention relates to tactile sensors.

More particularly the invention relates to tactile sensors of the kind (hereinafter referred to as the kind specified) comprising a compressible mat of electrically resistive material and an array of electrodes on at least one main face of the mat. Typically there is an electrode array on each main face of the mat, each array comprising a series of parallel spaced apart conductors with the conductors of one array extending transversely to the conductors of the other array.

In use of such a sensor information regarding the shape and position of an object contacting the sensor and the pressure exerted by the object can be obtained by scanning the resistance between pairs of the electrodes.

Known forms of tactile sensor of the kind specified suffer from a number of disadvantages, in particular that the variation of resistance with pressure exhibits hysteresis, and in the case of mats made of plastics materials, that resistance varies with the time that pressure is applied.

It is an object of the present invention to provide a tactile sensor of the kind specified wherein these disadvantages are alleviated.

According to the present invention in a tactile sensor of the kind specified the electrically resistive material comprises filaments coated with electrically conductive material.

The filaments are suitably fibres of a natural material, for example, wool fibres or a mixture of wool fibres and fibres of at least one other material such as cotton, in which case the electrically conductive coating material suitably comprises carbon particles.

Alternatively, the filaments may be fibres of a synthetic material, for example, aromatic polyamide fibres, in which case the electrically conductive material suitably comprises a graphite loaded polymer material.

The filaments may be bonded together with an adhesive.

The mat is suitably in the form of a cloth woven from yarn formed of filaments.

One tactile sensor in accordance with the invention will now be described by way of example with reference to the accompanying drawings in which:—

Figure 1 is a perspective view of the sensor;

Figure 2 is a circuit diagram of a scanning circuit for use with the sensor;

Figure 3 is a sectional view of the sensor of Figure 1 housed in a protective casing; and

Figure 4 is a graph illustrating the performance of the sensor.

Referring to Figure 1, the sensor comprises a mat 1 made of filaments coated with an electrically conductive material.

On each main face of the array there is provided an array of electrodes in the form of parallel spaced strips 3 or 5, the strips 3 on one main face extending at right angles to the strips 5 on the other main face.

In use the sensor is connected with a scanning circuit arrangement, one suitable scanning circuit being shown in Figure 2.

The circuit comprises a voltage source V whose negative terminal is connected to ground and whose positive terminal is connected via respective switches 7 and amplifiers 9 to each of the electrodes 5 on one main face of the mat. The electrodes 3 on the other main face of the mat are connected via respective switches 11 to one end of a reference resistor 13 whose other end is grounded. The ungrounded end of the resistor 13 is also connected to the input of a further amplifier 15 whose output is connected via respective resistors 17 to the inputs of the amplifiers 9.

In operation of the arrangement each of the switches 7 is closed in turn and whilst each switch 7 is closed, each of the switches 11 is closed in turn. The voltage across the resistance 13 is thus, in turn, representative of the resistance of the mat 1 at each of the locations on the mat 1 where an electrode 3 crosses an electrode 5.

The voltage across the resistance 13, which constitutes the output of the sensor, thus provides significant information regarding the shape, position and pressure exerted by an object placed on the sensor mat. The sensor output is suitably fed to a micro-processor (not shown) for storage, processing and display in any desired manner. It will be appreciated that the switches 7 and 11, which will normally be of the solid state type, will also be operated under the control of the microprocessor.

In one particular form of the sensor described above with reference to Figure 1 the mat comprises a piece of cloth woven from yarn consisting of cotton and wool fibres coated with carbon particles in the form of carbon black.

The carbon black is suitably applied by soaking the cloth in a suitable grease solvent loaded with carbon black or by spraying the carbon black onto the cloth. If desired, the fibres may be bonded together with an adhesive, for example, a synthetic rubber-resin adhesive. The adhesive is suitably applied by soaking the cloth in the adhesive. Application of the adhesive and carbon black may take place simultaneously, or successively, in either sequence, although care may need to be taken to ensure good electric contact between the mat and electrodes in some cases.

To facilitate its use, the sensor of Figure 1 is preferably housed in a protective casing.

In one such arrangement, illustrated in Figure 3, the spaced strips 3 or 5 forming each electrode array are supported on a protective backing sheet 19 or 21, for example of thin plastics material, lying on the side of the strips remote from the mat 1. The backings 19 and 21 project beyond the edges of the mat 1 with the space between the projecting parts of the backings filled with a suitable material, such as strips 23 of the same cloth as the mat is made from, and with the backings 19 and 21 bonded to the strips 23 or

other filling material.

The electrode array strips 3 and 5 suitably consist of metal foil or silicone rubber loaded with metal, e.g. copper or silver. Alternatively, the electrode array may be formed by removing the insulation from end portions of the conductors of a multi-way cable and laying the stripped conductors out in parallel spaced relation, the cable then providing a lead to the electrode array.

Figure 4 illustrates the variation of resistance with contact pressure at the point of application of the pressure for a sensor constructed as described above by way of example, using a cotton/wool mixture cloth approximately 0.3 mm thick, the application of carbon being carried out by soaking the cloth in 50 ccs of solvent loaded with 2.5 grams of carbon black.

In another particular form of the sensor described with reference to Figures 1, 2 and 3 the mat comprises a piece of cloth woven from a yarn consisting of aromatic polyamide fibres coated with a graphite loaded polymer material.

It will be appreciated that whilst in the sensors described above by way of example the mat is in the form of a cloth woven from yarn formed of filaments coated with electrically conductive material, this is not necessarily the case in a sensor according to the invention. Thus the mat may for example comprise filaments coated with electrically conductive material compacted into a matrix to form a felt-like material.

CLAIMS

1. A tactile sensor comprising a compressible mat of electrically resistive material and an array of electrodes on at least one main face of the mat wherein the electrically resistive material comprises filaments coated with electrically conductive material.

2. A sensor according to Claim 1 wherein the filaments are fibres of a natural material.

3. A sensor according to Claim 2 wherein the fibres are wool fibres.

4. A sensor according to Claim 2 wherein the fibres are a mixture of wool fibres and fibres of at least one other natural fibre.

5. A sensor according to Claim 4 wherein said other natural fibre is cotton.

6. A sensor according to any one of Claims 2 to 5 wherein said electrically conductive coating material comprises carbon particles.

7. A sensor according to Claim 6 wherein said carbon particles are in the form of carbon black.

8. A sensor according to Claim 1 wherein the filaments are fibres of a synthetic material.

9. A sensor according to Claim 8 wherein the fibres are aromatic polyamide fibres.

10. A sensor according to Claim 8 or Claim 9 wherein said electrically conductive coating material comprises a graphite loaded polymer material.

11. A sensor according to any one of the preceding claims wherein the filaments are bonded together with an adhesive.

12. A sensor according to Claim 11 wherein the adhesive is a rubber-resin adhesive.

13. A sensor according to any one of the preceding claims wherein the mat is in the form of a cloth woven from yarn formed of the filaments.

14. A sensor according to any one of the preceding claims wherein the electrodes consist of metal foil.

15. A sensor according to any one of Claims 1 to 13 wherein the electrodes consist of silicone rubber loaded with metal.

16. A sensor according to any one of Claims 1 to 13 wherein the electrodes are formed by removing the insulation from end portions of the conductors of a multi-way cable and laying the stripped conductors out in parallel spaced relation, the cable then providing a lead to the electrode array.

17. A sensor according to any one of the preceding claims having an electrode array on each main face of the mat, each array comprising a series of parallel spaced apart conductors with the conductors of one array extending transversely to the conductors of the other array.

18. A sensor according to any one of the preceding claims wherein the mat and the or each electrode array is housed in a protective casing.

19. A sensor according to Claim 18 wherein the protective casing comprises two sheets of material, one on each side of the mat, which project beyond the edges of the mat with the space between the projecting parts of the sheet filled with a material to which the sheets are bonded.

20. A sensor according to Claim 19 wherein the electrodes of the or each electrode array are supported on the adjacent said sheet.

21. A tactile sensor substantially as hereinbefore described with reference to Figure 1 or Figure 3 of the accompanying drawings.

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